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Event Monitoring and Observability for Industrial Systems on Azure Cloud

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Abstract: Cloud computing is a paradigm shift transforming data processing, communications and storage. It offers a cost-effective method that facilitates real-time data collection, storage and exchange by providing services such as compute, processing, storage and networking. This allows customers and enterprises to access any data or application from anywhere in the world over an Internet connection. This computation and availability model is a perfect fit for critical industrial applications such as power generation. The number and types of deployed sensors is on the increase requiring large scale storage, networking, and processing available on cloud platforms. We developed an Azure based application that generates a motion triggered event notification and provides access to the live video stream of the event location. The event is also recorded in a database and an email alert is sent to the subscribed operator. The implementation shows the importance of such systems for industrial applications requiring timely access to information.

Keywords: cloud computing, Azure cloud, livestream, monitoring

I. INTRODUCTION

The availability of embedded sensors, advancements in communications technologies and better signal processing techniques have increased the adoption of Internet of Things (IoT) technologies [1]. The industrial applications are being transformed with the use of IoT (Fig. 1). The use of sensors embedded into the industrial processes provide the benefits of greater visibility and control of the monitored process, maintaining a high standard and quality of the process, predictive maintenance of the infrastructure resources, and remote monitoring of the business assets [2]. IoT devices can sense, record and store the monitored data which can be analyzed for anomaly detection uncovering impending problems [3]. Integrating the IoT and surveillance functions in industrial applications can be used to build information frameworks [1].

Cisco has predicted the IoT market to be worth 14 trillion dollars by 2022 [4]. The integration of devices such as Radio Frequency Identification (RFID) readers, video cameras etc. within industrial processes improve the security and quality of production processes [4]. Video based surveillance and alarm system can ensure the security of the production facility.

A survey of IoT applications in industrial applications and corresponding application challenges are described in [1]. Efficient IoT management for industrial Wireless Sensor Networks (WSNs) is described using a cross-layer design for cloud-based RESTful web service [5]. Research potential and challenges of industrial WSN are described including hardware platforms, energy harvesting techniques, and service providers [6].

Cloud computing allows for off-site compute, processing, and network resources accessible over an Internet connection [7]. Many IoT platforms have emerged such as Android Things (Google), Azure IoT Suite (Microsoft) [1]. A common device for industrial IoT is surveillance camera as these can provide more

Fig. 1 IoT framework [24].

detailed information [1] not apparent through scalar sensors (temperature, vibration etc.). IoT has been widely adopted for automation in many types of enterprises [3]. Cloud Service Providers (CSPs) provide many advanced features such as Artificial Intelligence (AI) capabilities. The data and web applications deployed on the cloud are accessible from anywhere in the world, and over any device. The sensor values into the cloud from IoT applications can be autonomously monitored for any deviation from the stated rules.

Microsoft Platform as a Service (PaaS) components are becoming widespread for designing IoT application architectures [2]. Remote monitoring and connected factory being two solution accelerators [8].

The vision of Industry 4.0 cannot be realized without IoT [9]. The IoT application in industrial applications is termed Industrial Internet of Things (IIoT). Industry 4.0 by leveraging the technologies such as IIoT and cloud computing can provide large scale efficiencies in the production and manufacturing. The performance is improved with reduced energy consumption and maintenance costs [3]. Impact of Industry 4.0 on the production processes, changes and effects are described in [10].

Supervisory Control and Data Acquisition (SCADA) systems are used to control critical industrial processes through the visualization of data from sensors monitoring process [4], [11]. By incorporating the real-time consumption data and local production for smart grids can improve system efficiency [4]. Using more advanced queries on the edge device such as Raspberry Pi to monitor abnormal conditions and local decision making can reduce latencies inherent in IIoT and SCADA networks [12]. A survey of IoT from the industrial market perspective is provided in [13].

The monitoring devices can use a diverse set of protocols to send an alert such as Message Queuing Telemetry Transport (MQTT), Extensible Messaging and Presence Protocol (XMPP) and Simple Mail Transfer Protocol (SMTP) [4]. System reliability can be increased to as much as 94% using predictive maintenance based on the real-time data collection and analysis [4].

This paper describes the use of Azure cloud for designing an event notification system that provides better observability into the monitored process by integrating a video camera.

Rest of the paper is organized as follows: Section II describes related work. Section III covers the background information on Microsoft Azure. Proposed notification system is described in Section IV. The discussion is provided in Section V and conclusion in Section VI.

II. RELATED WORK

Many inferences can be drawn from the video coverage of critical infrastructures. A vision based automated system is proposed for monitoring the workers for Personal protective Equipment (PPE) compliance for their work to decommission a nuclear power station [14]. In comparison to sensor based monitoring techniques, vision based techniques are non-intrusive and can easily provide coverage of a larger area [14].

The term Industrial Internet by General Electric in 2012 [15], advocates the idea that all machines on the factory floor will have sensors which will make industrial operations very efficient and increase profits [4]. By incorporating an existing network of sensors, Microsoft has developed Azure Intelligent Systems Service (AISS) which can indicate all the equipment requiring attention on a network map [4].

A video monitoring system using smart cameras was proposed for predictive maintenance of machines [16]. Video cameras were used to monitor Programmable Logic Controller (PLC) devices. Virtual machines were used to host the web server and Wowza media streaming server on the Azure platform [16]. The focus of study however was enabling MPEG-DASH video traffic [16].

A real time data analytics platform has been proposed for large scale data analytics in industrial applications [17]. A prototype was implemented on the Azure platform that could collect and visualize data streams from diverse resources such as Open Platform Communications (OPC) server, and video capture from plant surveillance system [17].

A Raspberry Pi based IoT system for streaming data from a device to the Microsoft Azure and its storage and analysis is described in [18]. A proof of concept streaming application used IoT Hub and the data was stored in SQL database [18].

A cloud based bridge monitoring infrastructure for structure health monitoring is proposed in [7]. Diverse set of data was collected including video cameras to monitor vehicular traffic [7]. An innovative Human Machine Interface (HMI) was created with augmented reality using two-dimensional images and IoT for control and monitoring of a mechatronic system [9].

Use of Microsoft Azure IoT Edge was used to simulate a hydrocarbon well and the authors explored latency and intermittent network connectivity for edge computing [12].

An Azure cloud based IoT framework is proposed that incorporated Wi-Fi, Thread and LoRaWAN [19]. It was shown that a unified device management through Azure infrastructure overcomes the interoperability problems [19].

III. MICROSOFT AZURE

Windows Azure was released in February 2010, after that it was renamed as Microsoft Azure on March 2014 and is now the fastest growing cloud service provider. Microsoft Azure is the Microsoft cloud computing platform to develop, deploy, test, and manage applications through Microsoft managed data centers.

Microsoft Azure provides a vast variety of services and powerful, scalable, and fault-tolerant infrastructure that allows developers to build successful applications. Microsoft Azure is a popular cloud service platform and infrastructure; it provides many services at a low cost. The PaaS offers AI, data services, Web and mobile development, Content Delivery Network (CDN) and IoT components besides other services [2].

Microsoft Azure enables fast solutions and provides a lot of resources which may not be available in an on-premises infrastructure. Microsoft Azure services allow us to focus on building solutions rather than worrying about the underlying infrastructure. The Microsoft IoT platform is called Azure IoT and represents a set of managed services and solutions, including IoT Hub, IoT Edge, and IoT Central applications [20].

IoT Hub provides a reliable two-way communications from a large number of IoT devices [3]. Figure 2 shows the architecture of the IoT Hub. The IoT hub supports MQTT, XMPP, and HTTPS protocols for device communications [3].

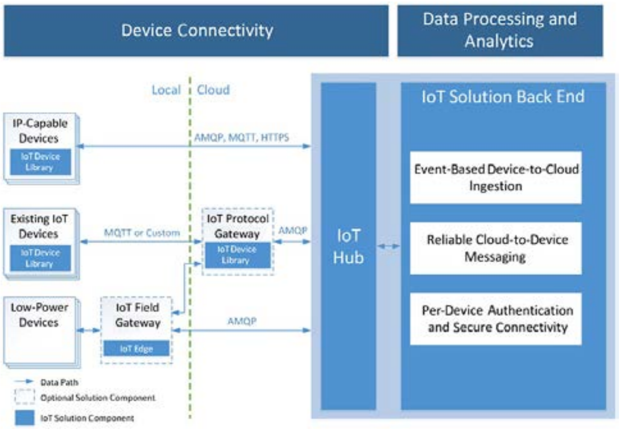

Fig. 2 Azure IoT Hub architecture [3].

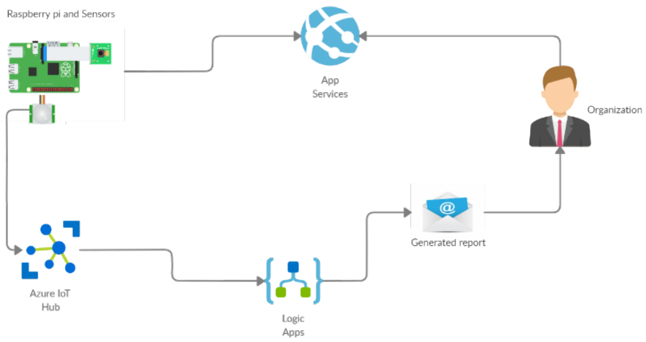

Fig. 3 System architecture and event flow.

A. Fabric Controller

Fabric controller is a part of the Azure platform. Fabric controller manages, controls, and monitors all the applications running on servers within the fabric. Fabric controller also decides where the new app should run and optimizes the hardware utilization. Fabric controller is a distributed app and it has visibility of all the servers, switches, load balancers and apps running within the platform.

B. Microsoft SQL Azure

Azure SQL is part of Azure PaaS. Azure SQL is a database engine which handles all the database management functions like upgrading data, data backups, patching data and monitoring without user interaction and thus enhances performance. By using Azure SQL, we can create high performance storage for apps.

C. Azure Platform App Fabric

Azure app fabric provides important services such as Service Bus, access control, caching and integration. Service bus provides secure connection and messaging between applications (distributed and disconnected apps) to exchange data. It can be utilized by using

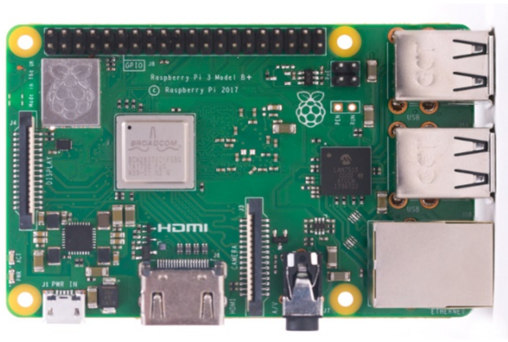

Fig. 4 Raspberry Pi 3B+.

different protocols and patterns. A new service can be created using the specific APIs and can start exchanging messages through Service Bus between any app and the platform. Access control provides access control services for managing authentication and identity in web applications. App fabric caching service provides capability to applications to quickly handle users. Caching service is distributed and maintained in memory, reducing the heavy load on the database.

D. Application Development

Developers can use local workstations for development of web app code on Azure. Visual Studio is one of the platforms for the application code development. Some of the languages supported by Azure platform for code development are JavaScript, Python, C#, C++, .Net, and Node.js. For application testing of the developed app, tools like automated unit test and web test are provided by Visual Studio.

IV. NOTIFICATION SYSTEM

A prototype system has been developed as a proof of concept for monitoring a process or zone of interest for motion detection and automatically generating an email alert along with streaming video of the incident.

A. Architecture

The architecture is shown in Fig. 3. We used Raspberry Pi [21] shown in Fig. 4, camera module, and Passive Infrared (PIR) sensor to develop the Azure based application. Raspberry Pi camera and PIR sensor provide input to Raspberry Pi. The PIR sensor reading is processed in Azure IOT Hub and camera images are processed using Motion package [22]. The Web App calls the app and an email is generated using Logic App. The report is generated and sent to the authorized operator.

B. Sensor Node

- **Raspberry Pi**

It is a Linux based minicomputer device, developed by Raspberry Pi foundation [21]. It is suitable for use in IoT projects and provides General Purpose Input Output

(GPIO) pins for interfacing sensor and actuator devices. It is very easy to integrate modules for Wi-Fi, and Bluetooth communications. Raspberry Pi also provides Camera Serial Interface (CSI) and webcam connectivity through USB port.

- **Camera Module**

We used Raspberry pi Camera module V2 which provides video streaming capability to the cloud platform. The camera module has Sony IMX219, 8 Megapixel sensor in it. We used it to send frames to web application using Motion package and then displaying it on web application front end. The camera module is supported on every model of Raspberry Pi.

- **PIR Sensor**

It is an electronic sensor which detects the infrared radiation from an object in its field of view and range. This sensor is commonly used in alarm systems that can passively detect motion in a monitored area, but it cannot tell us who or what it was that activated the sensor. All objects above zero temperature emit infrared radiation which is not visible to human eye but can be detected by PIR sensors.

- **Sensing Configuration**

Windows IoT core was installed on the Raspberry Pi. PIR sensor and the camera module were interfaced with the Raspberry Pi which can detect an intrusion and a notification can then be sent to Azure IOT Hub. The required libraries were installed and the code was written in Python language.

C. IoT Hub

Azure IOT Hub is a service provided by Microsoft which connects the IOT devices with Azure cloud seamlessly [2]. It offers device authentication so that two devices can not interfere with each other, full-scale management to increase the storage or processing power as required and full security for communications between device and Microsoft Azure. We can send telemetry data from the device to IOT Hub which supports multiple messages from the device. IoT hub supports many of the popular IoT protocols such as Advanced Message Queuing Protocol (AMQP), and MQTT [2].

D. Application Functionality

The application provides feature implementations for:

- Live video streaming
- Event notification through Email report service
- Data archiving and display

Live stream coming from Raspberry Pi runs in the Web application and an Email report is generated automatically whenever the PIR sensor detects a motion event. Any other type of sensor can also be interfaced for another type of event, such as temperature exceeding a threshold.

- **Live Streaming**

Motion package is a library specially built to monitor the live stream of any type of camera such as webcam, network/IP camera and Raspberry Pi camera. We used this for Raspberry Pi camera, and a web cam interfaced with Raspberry Pi. It can stream in real time without any latency, and an advantage is that it will automatically start whenever the Raspberry Pi is powered. Using Motion package, we developed the Raspberry Pi server which can stream video for authorized users through a connection from anywhere.

- **Email Reporting Service**

We can register as many IOT devices as required and the implementation provides us with a full scalable solution for our IOT devices. Logic app is a cloud service which can automate the process by using a set of rules for triggering an event. The event flow is shown in Fig. 5. The rule for intruder alert was set in the Logic App.

Azure service bus is responsible for delivering messages from IOT Hub to Logic App. The Service Bus will take message property indicating whether there is an intruder alert or not and compare that with the rule, which is set at Logic App, if it meets the criteria then Logic App will automatically activate the alert.

On an event trigger, the message will be generated to start SMTP service. We used Gmail SMTP protocol with Secure Sockets Layer (SSL) and Transport Layer security (TLS).

- **Data Archiving and Display**

The Azure SQL database fetched the stream from Universal Windows Platform (UWP) application on Raspberry Pi. The Web App hosted on the Azure platform displayed the stream from SQL database. Figure 6 shows the database interface.

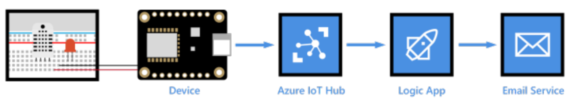

Fig. 5 Logic App information flow [23].

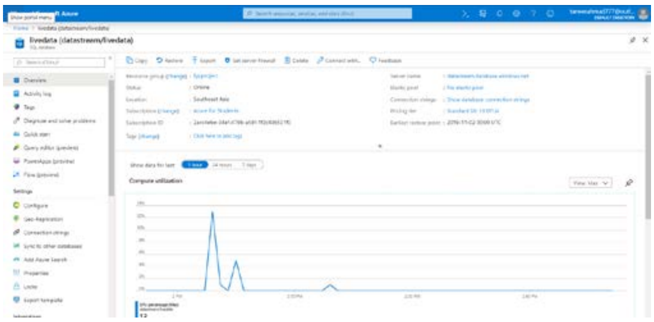

Fig. 6 Database on Microsoft Azure.

IV. DISCUSSION

There are many interesting use-cases for integrating the video data with industrial applications. In case of an event detection of an intruder's presence in a restricted area, a video snippet can automatically be recorded and sent to the authorities. The video data is also useful for event investigations such as spillages, fire incident, etc. which can provide an unambiguous confirmation of an uncertain occurrence.

Microsoft Azure IoT Hub allows for a two-way communication with the device [18]. It is thus possible to implement a two-way control and data applications where the operator is able to connect to the camera controls (pan, tilt, zoom) to gain better understanding of an area of interest.

The video feed could be connected to Azure Stream Analytics which is an event processing engine for automatic monitoring and analysis of data to identify hidden patterns for detecting an anomaly [2]. This can identify features of interest such as adoption of proper personal protective equipment by the workers in an industrial environment [14] or any abnormal behavior or condition.

In case of a large deployment of networked cameras it may be necessary to start video streaming only based on event detection (such as an intrusion) as for our system, or to run video analytics on the edge device and only transmit the information gathered [1].

The proposed prototype implementation can also be used for other application domains besides investigating events in industrial control applications.

V. CONCLUSION

Cloud platforms provide the advantages of a global access, scalability and cost effectiveness. We have implemented a notification system based on the Microsoft Azure platform. The event of interest was the motion trigger by a Passive Infrared (PIR) that sends an alert to the Azure IoT hub which is forwarded onwards to the Logic Apps sending an email notification to the authorized party. The system also allows access to the video livestream from the Raspberry Pi camera through a web application deployed on the Azure platform.

In our future work we will integrate more sensors with the Raspberry Pi such as to measure temperature and vibration that can provide preventive and predictive maintenance for industrial applications. The collected sensor data will also be integrated with analytics on the Azure platform for autonomous observability.

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